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Annex 1.2, Delayed Gamma-ray Measurements
Part 1, Gamma-ray Spectrum Measurements (Abridged)

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DELAYED GAMMA-RAY MEASUREMENTS

Part I—Gamma-ray Spectrum Measurements (Abridged)

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nomenon which results in the elimination of certain of the pulses. This effect is the result of cross talk from other channels and the reference channel (see Sec. 3.1.3).

Difference Interval: The difference between the zero interval and the free-run interval in microseconds.

Hash: From zero time to 300 to 400 μsec, disturbances on the line create spurious signals, called "hash," which mask the true signal.

The procedure that was followed is illustrated in the block diagram of Fig. 3.2. The details of the procedure were changed periodically to reduce errors and to take advantage of late arriving equipment ordered for the job. Initially, the scheme described in reference 2 was used to change the form of the data from magnetizations on the tape to deflection modulated oscillographs on 35-mm film. A section of a typical record, showing the signal pulses mixed with the marker pulses (which were controlled by the signal generator set to the reference frequency), is shown in Fig. 3.3. The film record was then read on microfilm readers, and the data were recorded in ruled data books. Each film record was first run across a lighted ground glass panel, and the reference markers corresponding most nearly to integral values of milliseconds from zero time were marked. The method of removal of data from the films is best illustrated by reference to a typical data sheet as portrayed in Fig. 3.4. Owing to the phenomenon of pulse cancellation, there are two basic types of pulse intervals to be determined. They are the total interval occupied by a group of successive pulses (which seldom exceed four in number) and the succeeding interval during which one or more pulses had been canceled. In the first column the number of intervals with no apparent missing pulses in the group is listed; intervals of cancellation are denoted by a dash. In the third column the number of full 20-μsec intervals (the basic reference marker interval in the initial system) was put down. The fraction, in tenths, of the last basic interval which transpired before the pulse occurred is recorded in the fourth column. This fraction determines the figure to be entered in the second column, which is the fraction of the basic interval from the signal pulse in question to the next marker pulse. Thus the sum of the entry in column 4 and the entry in column 2 of the next line down equals unity. The fifth column sums the readings in the second, third, and fourth columns. To keep track of the total elapsed time, the millisecond marker, if any, which occurs within the interval is shown in column 6. By multiplication by 20 and division by the number of intervals, the average interval per pulse in the group of pulses is determined.

The job of converting from pulse interval to counts per second requires a chart of voltage developed vs signal interval in microseconds, and a chart of photomultiplier anode current as a function of voltage was developed. If the preshot calibration mechanism functioned properly, the first chart is available for each individual channel from data contained near the beginning of each tape. Intervals can be determined from the tape which correspond to 0, 3, 8, 13, and 18 volts being applied to the modulator. The required function is obtained by plotting these five points and drawing a straight line through them, as shown in Fig. 3.5. The second chart is universal in that it applies to all channels. It is shown as Fig. 3.8 of reference 3. The actual voltages corresponding to given intervals were computed from the zero interval and the slope value which most nearly coincided with the five points obtained from the record, rather than using the less accurate method of picking them from a drawn graph.

3.1.2 Limitation in Precision of Data Due To Reduction of Data and Malfunctions of Equipment

The first error arises from the assumption that the frequency variation of the reference signal during the run was negligible. The first estimate of the variation made from observing the Lissajous figure of the reference wave and the signal generator controlling the reference markers on the film was found to be low, and all channels with significant information were rerun, using a different system. About this time it was also discovered that the basic frequency of the reference signal was not 5000 cycles/sec (on playback at 1/100 of the recording speed) but 1250 cycles/sec. This phenomenon remained undiscovered for so long owing to the fact that the reference track amplifier in the reproducer was tuned sharply to 5000 cycles/sec

greater sensitivity so obtained would allow reduced voltages applied to the apparatus, thereby reducing the probability of arc-over due to ionization in the air from the radiation. The leads to the photomultiplier should be radiation shielded to as large an extent as possible without introducing serious scattering errors.

It is recommended that future IvT installations be enlarged to accommodate all electronic equipment and associated power supplies below ground with sufficient shielding to prevent trouble due to radiation ionization. If a large enough hole is provided to permit working in a sitting down position inside the shelter and a trap-door entrance is provided at the back so that special equipment is not required to close up the installation, many of the difficulties encountered on this test could be avoided. The battery rack and relay installation should use hermetically sealed units to overcome failures of relays and switches due to dust particles. Some of the failures of IvT and spatial unit calibrations were due to Potter & Brumfield SM5DG miniature relays. These relays should be avoided.

(2) Spatial Distribution Vs Time. The spatial electronics suffered from insufficient shielding of the power and switching equipment. If this kind of measurement is done again, it is recommended that the concrete block be enclosed to accommodate the ancillary equipment. The forward wall would shield from the direct radiation, and just a small thickness at the sides and back would reduce the secondary radiation to a value which would not affect electronic components. This incidentally would eliminate errors due to ground capture gammas entering the back of the collimator. The calibration system was apparently not sufficiently reliable, and it is recommended that some means of making the calibration more foolproof, such as duplication, be used.

(3) Spectral Distribution Vs Time. The main fault found with the spectrometer electronics was biting off more than could be properly digested. Had there been time for intensive testing of the units, both individually and as a system, prior to production runs, the apparatus would have stood a better chance for success. From the intensity levels observed in this test, it is now possible to predict, at least within a factor of 50, what the intensity at a given time past +1 msec will be, and therefore the complexity required for a large dynamic range becomes unnecessary. The working conditions inside the spectrometer shelter were nearly intolerable. It is recommended that a more efficient ventilation system be devised in future installations. The general recommendations concerning maximum prefabrication for installation and reduction of complexity of calibrations apply particularly here because of the vast amount of circuitry involved.

(4) Recorder Recommendations. If the same magnetic recorders are used again in a future test, time should be allowed for a complete dry run in the laboratory to determine the cause of the cancellation of pulses and to remedy it. Minor changes to the recorders should include current limiting resistors from B^+ to the blocking oscillator tube, fuses local to the recorders, and input volume controls for each channel. A more reliable tube should be substituted for the 6V6 in the crystal oscillator circuits. More ventilation should be provided for the recorder shelter because of fumes from charging batteries. In any future test, provision should be made for the immediate re-recording of data on duplicate tapes or on film to be kept in case of mishap to the primary tapes. The crystal frequency should be reduced to within the range 125 to 250 kc/sec.

Other modifications should be made to the recorders. The reference frequency amplifier should have a flat response from +10 to −10 per cent of the nominal reduced reference frequency and should fall off sharply on either side of the pass band. The amplifier should be redesigned for no tendency to oscillation and for lower noise and hum originating in the input circuits. The input circuits of the signal amplifiers should also be modified for lower noise and hum pickup. The d-c supply for the heaters of the low-level tubes should be made integral to the reproducer unit. There should be tape guides near both the take-up and pay-out reels to fix more definitely the position of the tape on the reels. There should be a vertical adjustment on the band assembly to maximize the response without forcing the tape out of its natural path. Investigations should be made into the procurement of a more flexible magnetic tape that is less subject to humidity effects.

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